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SUBJECT: Urine Output Variables and M071/73 Sampling Requirements Case 105-5

DATE: June 26, 1970

FROM: L. D. Sortland

ABSTRACT

During the past year there has been considerable controversy over the urine sampling strategy and the state of the returned samples for the Skylab Medical Experiments M071 and M073. Decisions have recently been made to return frozen samples from a daily pool collected on orbit for each astronaut.

Experiment requirements call for a representative 120 ml sample from each crew member each day. One of the sampling strategies which had been under consideration involved the return of separate, fixed volume samples from each urine void. In this strategy, the individual samples collected from each crew member over a 24 hour period would be pooled in proportion to the original void volume after return to earth. In an effort to reduce the weight and volume of returned samples, the Centers had proposed reducing the individual sample volume to 65 ml.

This paper examines the validity of the reduced volume sampling strategy based upon urine void data from Gemini 7 and from the 60 day, four man chamber study carried out by McDonnell-Douglas Astronautics Company. The conclusion is that with a 65 ml sampling volume, failure to reconstitute a representative daily sample of at least 120 ml could be expected on about 7% of the total man-days. The recently adopted strategy of on orbit pooling for the single 120 ml daily sample for each crewman resolves this problem.

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MEMORANDUM FOR FILE

INTRODUCTION

The sampling protocol for Skylab Medical Experiments M071 and M073 calls for a sample of at least 120 ml from a daily pool of the urine voids for each of the three crewmen. One strategy which had been under consideration involved the return of fixed volume samples from each void, with pooling in proportion to the original void volume after return to earth.

From a return weight and volume standpoint, it would be desirable to minimize the size of the fixed volume sample. This paper examines the question of how the sample size for individual voids affects the ability to reconstitute a representative 120 ml daily pool. A mathematical analysis is carried out using pertinent data on individual urine production parameters taken from a ground-based closed chamber study and from Gemini 7.

MATHEMATICAL ANALYSIS

The experiment protocol requires that a representative 120 ml sample of the average daily urine output of each crewman be available post-flight for chemical analysis. In mathematical terms, the proposed proportional recombination method to satisfy this requirement can be expressed by:

$$\text{Reconstituted Volume} = \sum_{i=1}^{i=m} \frac{V_i v}{V_{max}} \geqslant 120 \text{ ml} \qquad (1)$$

where:

m = number of voids/man/day

V_i = $i\underline{th}$ void volume

V_{max} = maximum void volume on this day

v = fixed sample volume per void

This expression can be simplified

$$\frac{v}{V_{max}} \sum_{i=1}^{i=m} V_i \geqslant 120 \qquad (2)$$

Since $\sum_{i=1}^{i=m} V_i$ = total void volume/day, V_t, equation (2) can be reduced to

$$\frac{v}{V_{max}} V_t \geqslant 120 \qquad (3)$$

or

$$\frac{V_{max}}{V_t} \leqslant \frac{v}{120} \qquad (4)$$

Since the requirements for analysis are 120 ml, then

$$\frac{V_{max}}{V_t} = \frac{v}{120} \qquad (5)$$

would satisfy the experiment protocol.

Figures 1 and 2 are graphical representations of Equation 5. Figure 1 shows the ratio of the maximum single void volume to the daily void volume as a function of the sample volume required to satisfy the 120 ml requirement. Figure 2 is a plot of the maximum single void volume permissible versus the daily void volume with sample volume as a parameter. To place these curves in perspective, the average V_t for the 60 day, 4 man McDonnell-Douglas (MDAC) closed chamber study is included. The details of this study are contained in the next section.

The average void number/day for the MDAC study was 4 with a range of 2 to 7. Since the primary difficulty with proportional reconstitution occurs when the number of voids/day is 3 or less, consider the example of two urinations/day. If v = 60 ml, then each void would have to be identical in volume. Even if v = 70, V_{max}/V_t would have to lie between 0.5 and 0.583.

This means, for example, that for a total volume of 600 ml/day V_{max} would have to be between 300 and 350 ml. A relaxation in these range limits can be achieved by increasing the sample size to 80 ml/void or more. This, however, increases the total sample weight and volume obtained.

DATA ANALYSIS

Data from a number of sources were obtained in order that the urine output parameters could be analyzed with respect to proposed sampling mode. Table I is adapted from the Bioastronautics Data Book[1] and illustrates the wide variability in urine output depending upon the environmental conditions and fluid intake. Attention is brought to Note 1 in this Table which points out the caution under which the data must be considered. The values shown in Table I for space cabin simulators are practically identical to those reported by Shook and Thomas,[2] shown in Table II, for a series of chamber studies conducted by MDAC. These authors concluded that an average void volume/man/day of approximately 1000 ml with a range from 730 to 1340 ml is a good value for system design.

The most extensive single test to date is the MDAC 60 day chamber study with 4 men. The volume and time of each urination were recorded, and a summary of the output parameters for each individual is contained in Table III. The data were analyzed to determine: (1) diurnal variations (see Figure 3), (2) maximum and minimum values, and (3) the number of voids/day distribution. Average values were also computed. It is interesting to note that 24% of the voids occurred in the first hour after the sleep period and accounted for 34.5% of the total volume. The average void volumes for the first hour were 66% larger than those for the rest of the awake period.

The range in single and daily void volumes was quite large and appeared to be common to all the crew. The distribution of single void volumes is shown in Figure 4 and that for daily volumes in Figure 5.

Table IV contains the urine output parameters for the 14 day Gemini 7 mission. Even though there was a considerable difference in the urine output between the two men, the average values agree quite well with those from the chamber studies. Astronaut I produced 30% more volume than did the crew on the MDAC test, and it is possible that his 10 pound weight loss during flight may have contributed. However, Astronaut II had a 6 pound weight loss and his volume output was well below that of the MDAC crew.

In considering these actual flight results, it must be kept in mind that only two individuals were involved for a relatively short period of time in a highly stressful endeavor under conditions of weightlessness, extremely limited living space and unesthetic bathroom facilities. Considering the known wide variability in human beings and the above environmental factors, the agreement between the chamber and spaceflight studies in the area of urine output parameters is quite close.

The sampling protocol requiring a fixed volume sample from each void was applied to the MDAC and the Gemini 7 data. The number of days that a 120 ml representative sample could not be reconstituted was computed as a function of sample volume. These results, contained in Table V, show the percent failure rate to obtain a 120 ml volume for each individual, as well as the average values. Failure rates for the two sources of data are, for all intents and purposes, identical. The sample volume required to ensure a reconstituted, representative 120 ml volume is approximately 80 ml.

Once the failure rates are known, the next question to be considered is: what is the maximum representative volume that can be reconstituted on those days of failure.

At the time that the decision was first made to return frozen urine samples, the guidelines specified 65 ml samples/void. Based on this volume, the maximum representative sample possible was computed for those days of failure and the results are contained in Table VI. For both MDAC and Gemini 7 data, failures would have occurred about 7% of the time. Half of these failures would have given volumes which were 110 ml or more. Only on one occasion did the largest possible representative volume turn out to be less than 100 ml.

Throughout the analysis, the variable most heavily involved with failures was the number of voids per day. Table VIII and Figure 6 summarize the data from MDAC and Gemini 7. On those two voids/day occasions, 64% resulted in failure, and these accounted for 47% of the total failures. Of the three voids/day 9.2% failed and accounted for 42% of the failures.

CONCLUSIONS

On the basis of the spaceflight data examined, values for inflight urine output parameters appear to be in good agreement with those derived from ground-based chamber tests. A wide variation can exist between individuals on any one day, and for the same individual on different days. Average values, however, quite consistently approach 1000 ml/man/day and 4 voids/man/day.

Based on the MDAC and Gemini 7 data, the fixed volume sampling per void procedure would require about an 80 ml sample volume to fulfill the experimental requirements established for M071 and M073. A 65 ml sampling strategy would result in less than the required 120 ml representative volume about 7% of the time. On the occasions when failure to obtain 120 ml occurs, it is usually possible to obtain 100 ml samples.

The Skylab Program has recently decided to adopt the strategy of on orbit pooling. A daily pool will be collected for each crewman from which a 120 ml sample will be extracted for freezing and return to earth. The results of this study support that decision insofar as they show that the previously proposed 65 ml fixed volume sampling protocol would not have met the experiment requirements.

for

1011-LDS-sje L. D. Sortland

Attachments
Figures 1 thru 6
Tables I thru VII

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance and cooperation of R. E. Shook, McDonnell-Douglas Astronautics Company, Western Division, in obtaining the experimental data on urine production for the 60 day chamber study, and of Dr. Leo Lutwak, Cornell University, for supplying the Gemini 7 data.

REFERENCES

1. Bioastronautics Data Book, NASA SP-3006.

2. R. E. Shook, E. C. Thomas, "Urine Output Parameters for Space Cabin Environments", presented at the Aerospace Medical Association, 40th Annual Meeting, San Francisco, California, May, 1969.

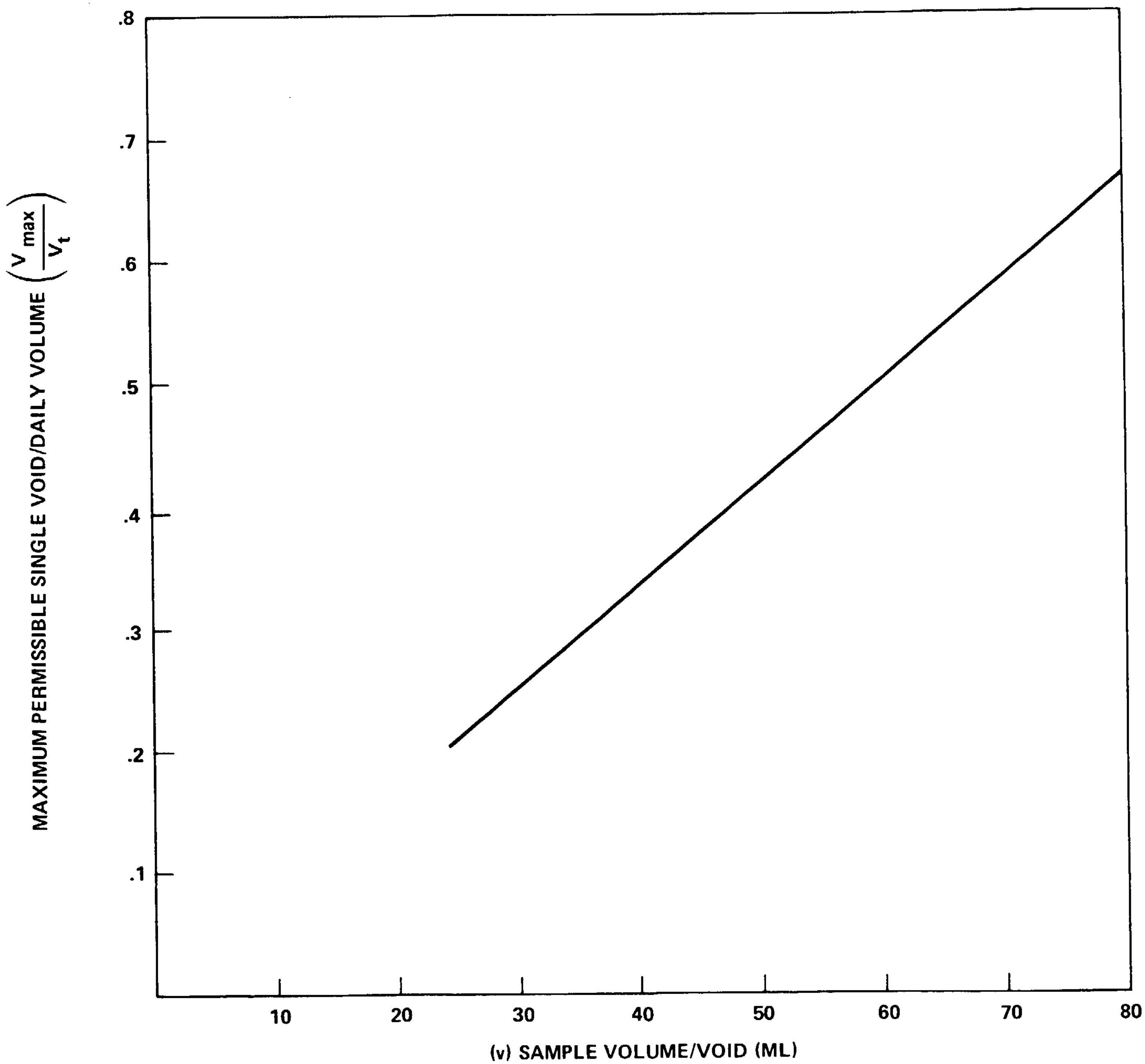


FIGURE 1 - EFFECT OF SAMPLE VOLUME ON THE RATIO OF MAXIMUM PERMISSIBLE SINGLE VOID VOLUME TO DAILY VOLUME

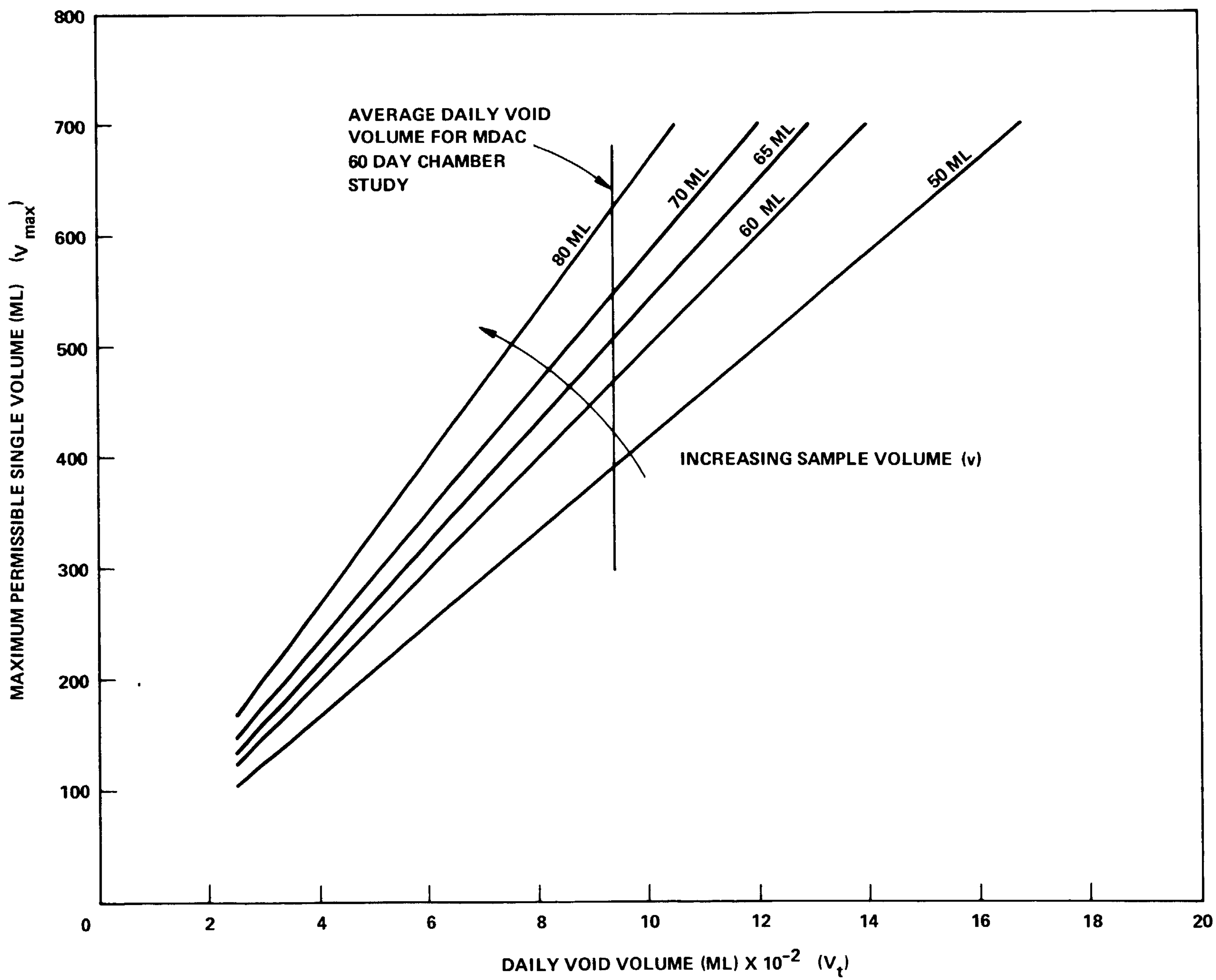


FIGURE 2 - MAXIMUM PERMISSIBLE SINGLE VOID VOLUME AS A FUNCTION OF DAILY VOLUME

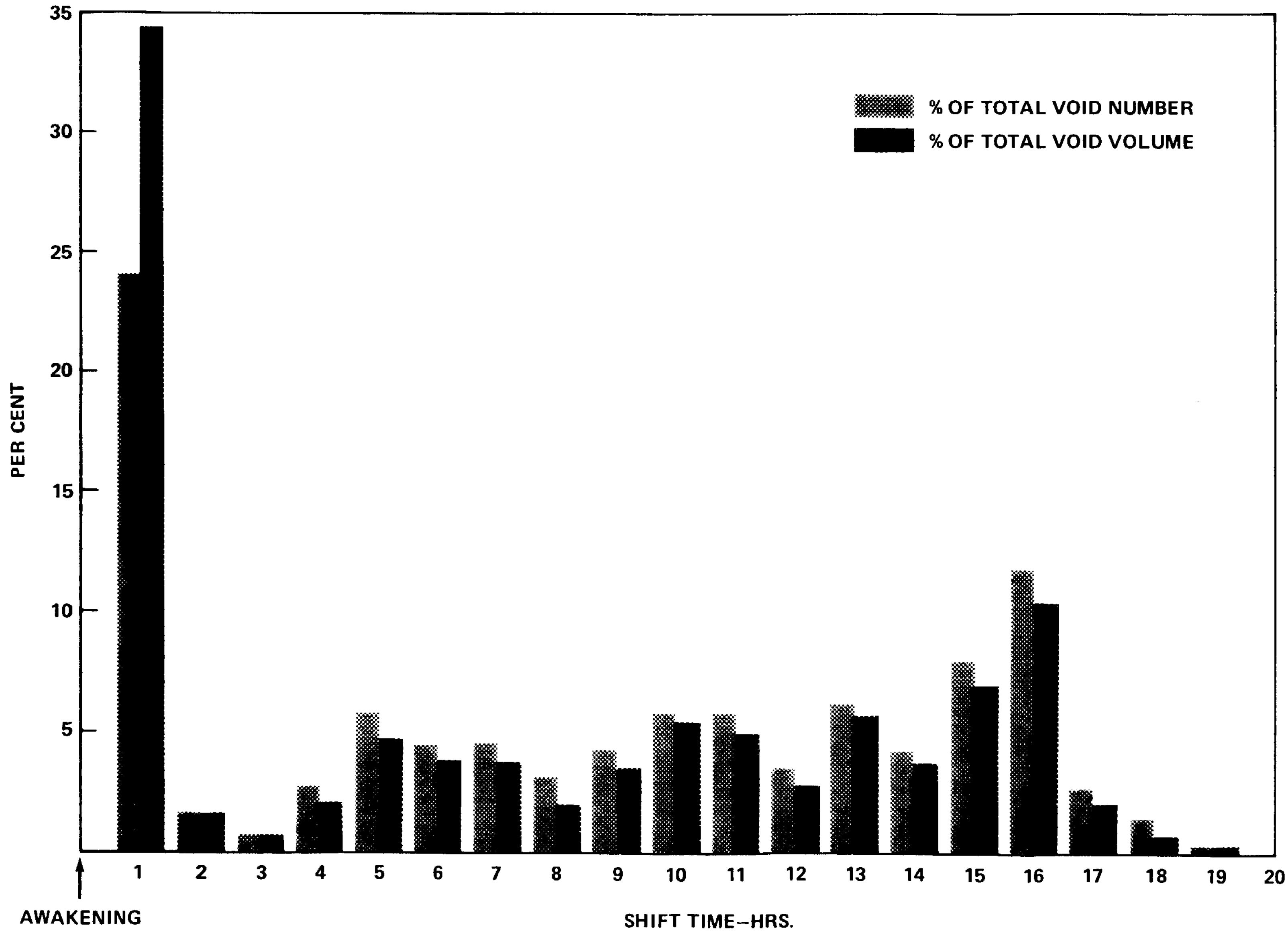


FIGURE 3. DIURNAL DISTRIBUTION OF VOID NUMBER AND VOLUME FOR MDAC 60 DAY CHAMBER STUDY

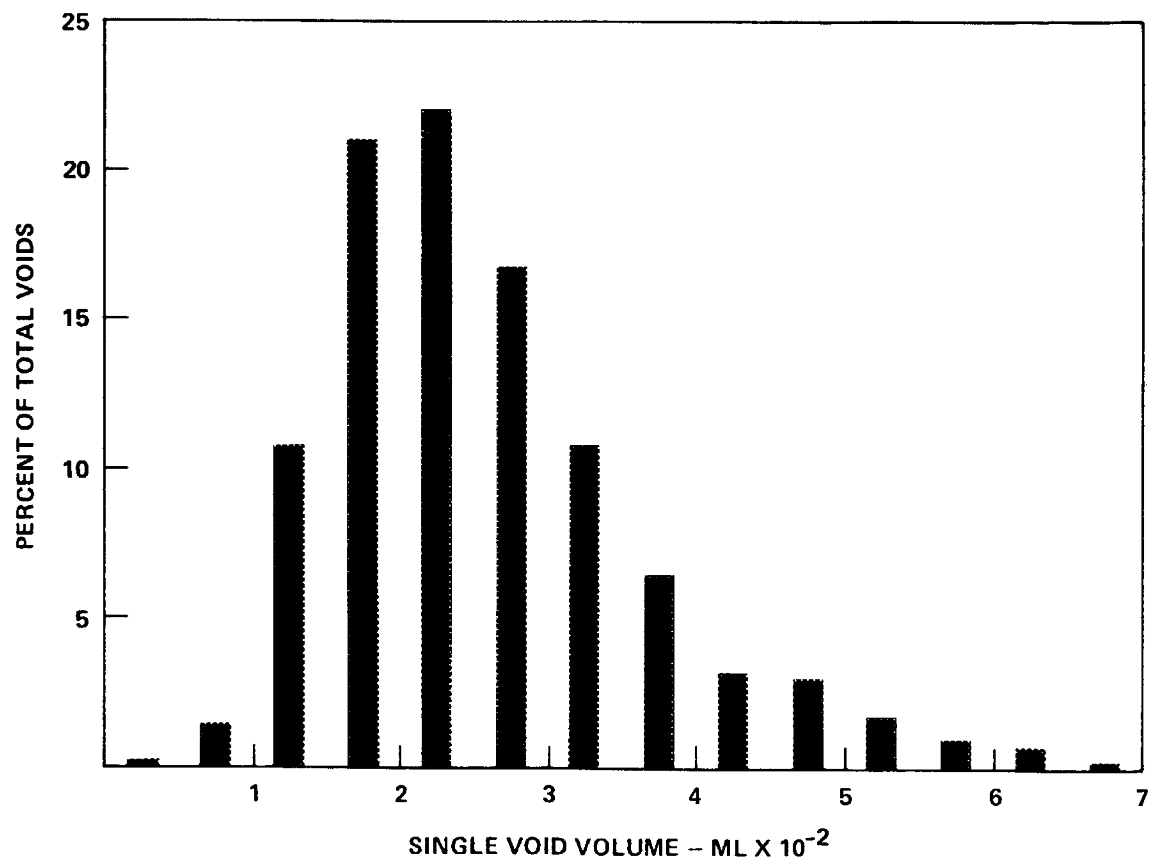


FIGURE 4. DISTRIBUTION OF SINGLE VOID VOLUMES FOR MDAC 60 DAY CHAMBER STUDY GROUPED IN 50 ML INCREMENTS

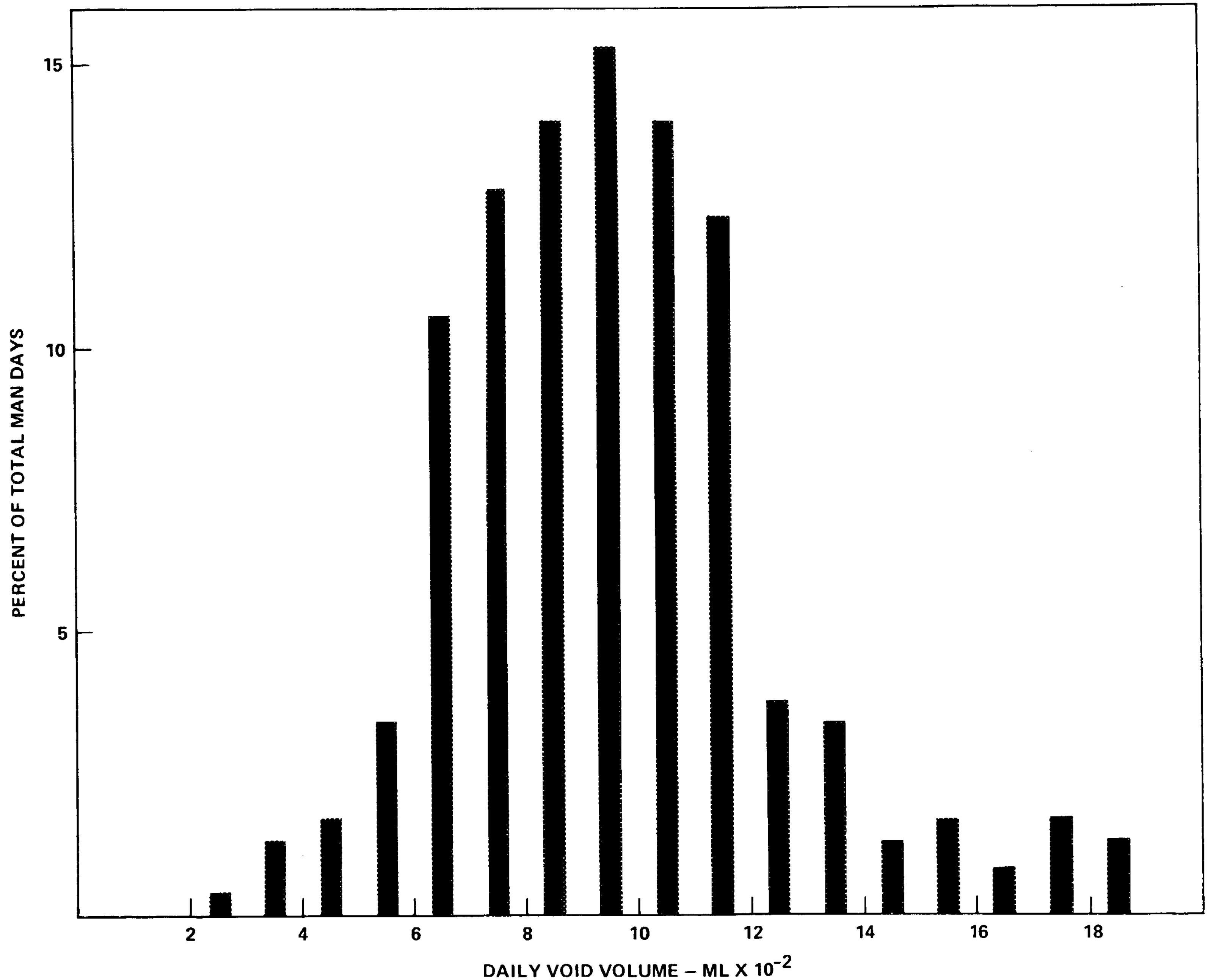


FIGURE 5. DISTRIBUTION OF DAILY VOLUMES FOR MDAC 60 DAY CHAMBER STUDY GROUPED IN 100 ML INCREMENTS

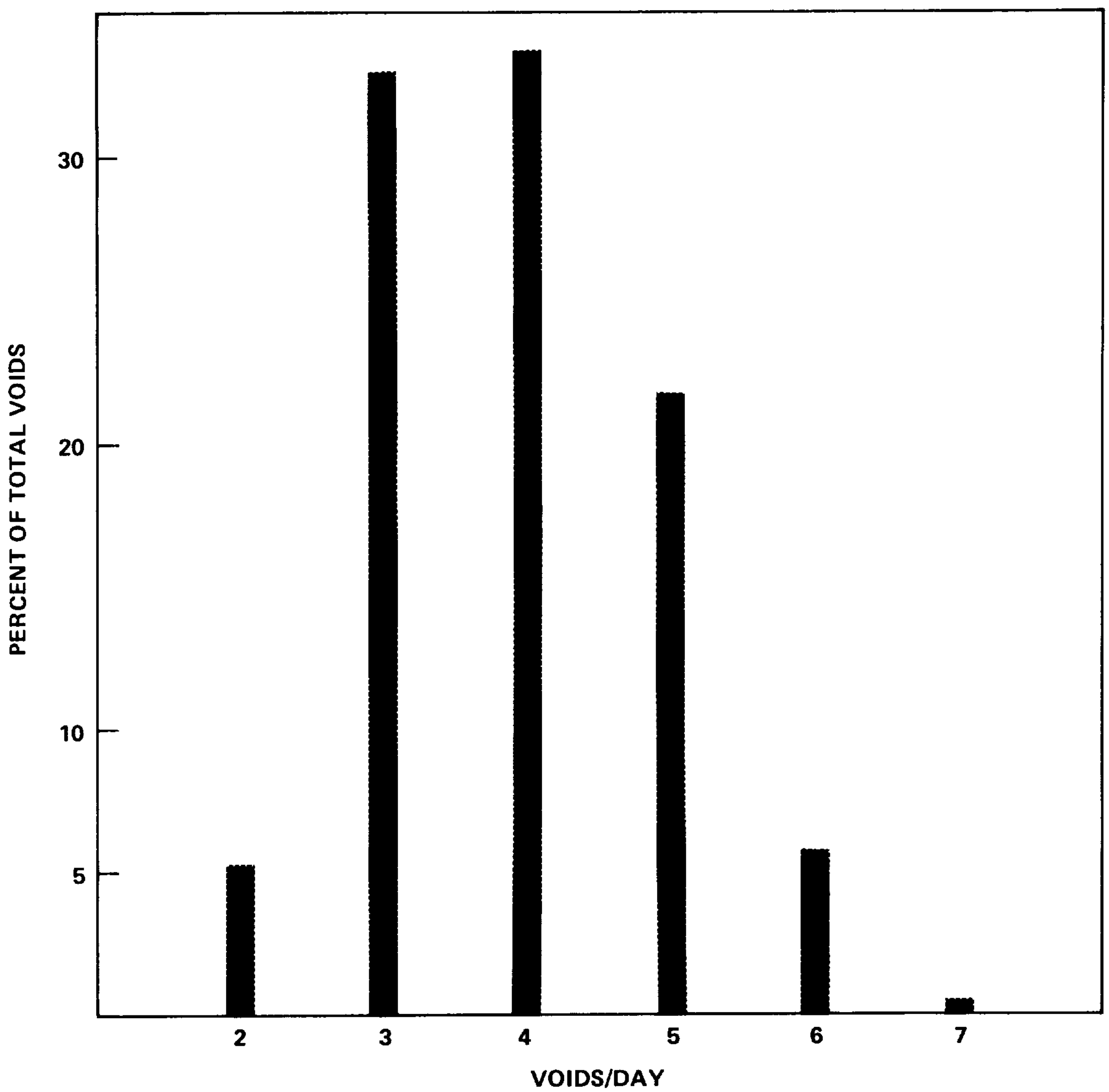
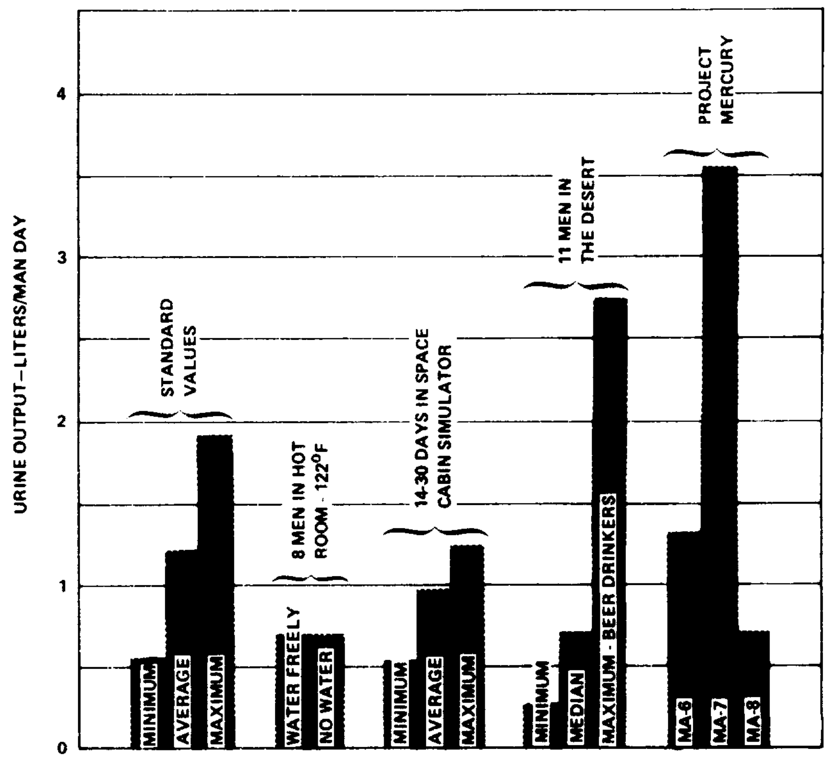


FIGURE 6. DISTRIBUTION OF THE NUMBER OF VOIDS/DAY FOR MDAC 60 DAY CHAMBER STUDY

TABLE I

URINE OUTPUT PARAMETERS*



Note 1: "[The data in this graph]...are particularly subject to the warning that these are biological data with considerable individual variation. Furthermore, many of the data are quite old, and the conditions under which material was collected are often not described. Original literature citations are to be found in the reference list, but in many instances the data in standard handbooks and textbooks have been repeated over and over from one rather skimpy original source. The average values and ranges presented here are intended only as general guidelines. Specific design problems will in most cases require individual observation of the subjects and new experimental information."

Note 2: "In the orbital flights of Project Mercury, urine production is seen to have been quite varied. In one flight, MA-7, there was a real diuresis during the 4.5 hour weightless period. In MA-6 and MA-9 there was a rather low urine volume, which may be related to the high rate of sweating observed. The data for MA-9 show the 24-hour rate calculated from urine volume in 34 hours of weightlessness."

*Adapted from Bioastronautics Data Book (1).

TABLE II

URINE OUTPUT PARAMETERS IN MDAC CHAMBER STUDIES
WITH 24 HOUR/DAY OCCUPANCY*

Completion Date	Dec. 1964	Feb. 1965	March 1966	Feb. 1968	April 1968
Test Duration (days)	12	30	5	5	60
Number of Subjects	4	4	2	4	4
Urine Output (liters)	43.3	127.3	9.1	14.6	226.4
Average Daily Volume/Man (ml)	857	1060	912	730	943
Maximum Daily Volume/Man (ml)	1860	1650	1300	1500	1825
Minimum Daily Volume/Man (ml)	80	500	387	575	270
Maximum Volume/Single Voiding (ml)	740	530	550	540	700
Single Voiding Range (ml)	-	-	73-550	150-540	25-700
Mean Temperature (°F)	-	76.8	-	-	78.9
Test Pressure (psia)	7	7	7	7	7

Note: In the 60 day test, the average number of urinations per day was 4 with a range from 2 to 7 and a standard deviation of ±1.5. The average void volume was 238 ml.

*Adapted from Shook and Thomas (2).

TABLE III

INDIVIDUAL URINE OUTPUT PARAMETERS FOR MDAC
60 DAY CHAMBER STUDY

	I	II	III	IV	Ave.
Total Void Number	242	217	223	270	238
Ave. Void Number/Day	4.02	3.62	3.72	4.50	3.97
Number in 1st Hour After Awakening	62	49	57	60	57
Ave. Void Volume (ml)	244	267	247	202	240
Ave. Void Volume in 1st Hour (ml) After Awakening	350	412	352	265	345
Ave. Void Volume in Remaining Time (ml)	212	225	210	183	208
Ave. Void Volume/Day (ml)	985	965	916	905	943
Maximum Daily Volume (ml)	1475	1825	1825	1350	1619
Minimum Daily Volume (ml)	500	475	270	575	455
Maximum Volume/Single Void (ml)	700	700	650	450	625
Minimum Volume/Single Void (ml)	100	25	40	75	60
Distribution of Number of Voids/Day*					
2	0	6	6	0	3
3	14	22	22	10	17
4	28	24	16	16	21
5	15	6	12	23	14
6	2	1	3	8	3.
7	0	0	0	1	.

*Based on 59 complete days in the chamber.

TABLE IV

URINE OUTPUT PARAMETERS FOR GEMINI 7

	I	II	Average
Total Void Number	48	44	46
Samples Lost	1	4	
Average Void Number/day	3.43	3.14	3.29
Average Void Volume/day (ml)	1255	709	982
Average Volume/Void (ml)	374	248	306
Maximum Daily Volume (ml)	2405	917	
Minimum Daily Volume (ml)	574	614	
Maximum Volume/Single Void (ml)	687	421	
Minimum Volume/Single Void (ml)		43	
Distribution of Voids/Day			
2	2	0	
3	7	12	
4	3	2	
5	1	0	
6	1	0	

Note 1: Mission duration was 14 days.

Note 2: The mission day is based on 24-hour intervals beginning at lift-off.

TABLE IV

URINE OUTPUT PARAMETERS FOR GEMINI 7			
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Total Void Number	48	44	46
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Minimum Volume/Single Void (ml)		43	
Distribution of Voids/Day			
2	2	0	
3	7	12	
4	3	2	
5	1	0	
6	1	0	

Note 1: Mission duration was 14 days.

Note 2: The mission day is based on 24-hour intervals beginning at lift-off.

TABLE V

PROPORTIONAL RECONSTITUTION - PERCENT FAILURE RATE AS A FUNCTION OF SAMPLE VOLUME

	Sample Volume, ml			
	50	60	70	80
Gemini 7				
Crewman I	35.7	14.2	7.2	0
Crewman II	35.7	7.2	0	0
Average	35.7	10.7	3.6	0
MDAC 60 Day Study*				
Crewman I	15.2	1.7	0	0
Crewman II	55.9	22.0	8.5	0
Crewman III	49.1	25.4	8.5	0
Crewman IV	0	0	0	0
Average	30.1	12.3	4.3	0

*Based on 59 complete days in the chamber.

TABLE VI

REDUCTION IN RECONSTITUTED VOLUME
FOR THE DAYS OF FAILURE - ASSUMING 65 ML SAMPLE VOLUMES

MDAC 60 Day Study

Crewman	Day of Occurrence	Number of Voids	V_H^*	Volume** Deficiency
I	58	4	111	9
II	10	2	110	10
	13	2	106	14
	15	2	97	23
	22	3	116	4
	53	3	114	6
III	5	2	117	3
	12	3	118	2
	13	2	100	20
	28	3	115	5
	30	3	118	2
	33	5	112	8
	43	2	104	16
	47	3	103	17
	49	3	106	14
	50	2	117	3
	57	3	100	20
IV	- 65 ml samples would satisfy requirements			
		Gemini 7		
I	2	2	118	2
	3	2	102	18
II	- 65 ml samples would satisfy requirements			

* V_H is the maximum representative volume which could be reconstituted assuming 65 ml sample volumes were taken.

** The difference between the 120 ml required and V_H.

TABLE VII

EFFECT OF VOIDS/DAY ON FAILURE RATE*

Number of Voids/Day	2	3	4	5	6	7
No. of Occurrences on Gemini 7	2	19	5	1	1	0
No. of Occurrences on 60 Day Run	12	68	84	56	14	1
Sum	14	87	89	57	15	1
No. of Occurrences Resulting in Failures	9	8	1	1		
% of Occurrences Resulting in Failures	64.3	9.2	1.1	1.8		

*Based on a 65 ml sample volume/void.

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FROM: L. D. Sortland

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